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Indian Standard
METHOD OF TEST FOR TEMPERATURE COEFFICIENT OF PRECISION RESISTOR WIRES

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METHOD OF TEST FOR TEMPERATURE COEFFICIENT OF PRECISION RESISTOR WIRES

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Indian Standard

METHOD OF TEST FOR TEMPERATURE COEFFICIENT OF PRECISION RESISTOR WIRES

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 13 June 1966, after the draft finalized by the Electrical Instruments and Meters Sectional Committee had been approved by the Electrotechnical Division Council.

0.2 This standard has been prepared to meet the need for having a standard method of test for the determination of resistance/temperature relationship of alloy wire used in the manufacture of precision resistors.

0.3 In the preparation of this standard, assistance has been derived from B.S. 3467 : 1962 ' Method of test for temperature coefficient of resistance of alloy wire for precision resistors' issued by the British Standards Institution.

0.4 This standard contains a clause which permits the purchaser to use his option for selection to suit his requirements. The relevant clause is **12.1.2** (Note).

0.5 In reporting the result of a test made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS : 2-1960*.

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1. SCOPE

1.1 This standard describes a procedure for determining the change of resistance with temperature of alloy wire (including material of non-circular section) used for resistance standards and precision resistors for electrical apparatus. The maximum range of temperature covered is $-65°C$ to $+200°C$. This standard provides for the presentation of the results in the form of a graph, as a change of resistance between specified temperatures, or as the coefficients in a resistance/temperature equation.

2. TEMPERATURE COEFFICIENT OF RESISTANCE

2.1 Unless otherwise stated, ' Temperature coefficient of resistance' is the constant-mass temperature coefficient, that is, that of a conductor with terminals fixed to it, but left free to expand or contract.

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*Rules for rounding off numerical values (*revised*).

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3. TEST SAMPLE

3.1 The test specimen shall be of a length that will give a resistance that may be measured to the required accuracy.

3.2 Care shall be taken that the strains introduced in the preparation of the specimen are as small as possible.

3.3 If the wire is insulated, it may be wound in a circular coil, with or without a former, not less than 5 cm in diameter.

3.4 If the wire is not insulated, it may be wound on an insulating former in a manner that will not introduce strains in the wire when subjected to temperature changes.

3.5 The tension used in winding shall be no more than sufficient to produce a neat coil of insulated wire or to prevent the touching of adjacent turns when bare wire is wound on an insulating former.

3.6 For fine wires of sufficiently high resistivity, straight wire specimens may be used.

4. TERMINALS

4.1 If the resistance of the specimen is less than 100 ohms, it is preferable to use both current and potential leads in measuring the resistance. A wire shall then be brazed, soldered or welded close to each end of the specimen for use as a potential lead. The heating involved in this operation may modify the properties of the alloy over a short distance. To reduce the effect on the measured values to a negligible amount, the specimen should be not less than 50 cm in length.

4.2 If the two-terminal method of resistance measurement is used, the terminals may be clamped or, alternatively, a copper wire may be brazed or soldered to each end of the specimen for use as a terminal. In either case, the resistance of the terminal connections shall be less than 0·02 percent of test of the specimen.

4.3 In coils made of fine wire where there is not sufficient rigidity in the coil itself to furnish a satisfactory support for the terminals, short lengths of thin glass or ceramic rod may be bound across the coil to act as struts and furnish an anchorage for the terminals.

5. PRECONDITIONING

5.1 The prepared specimen shall be subjected to a temperature of $140° \pm 5°C$ for not less than 16 hours for alloys of the 80/20 nickel/chromium type and of the copper/manganese type with an approximate composition

84/12, and to a baking period specified by the manufacturer for other alloys. The purpose of this treatment is to stabilize the resistance of the wire, and the measured characteristics of the specimen after treatment shall be considered as the true temperature resistance characteristics of the wire.

6. APPARATUS

6.1 The apparatus for making the test shall consist of one or more baths for maintaining the specimen at the desired temperatures, thermo-meters for measuring the temperatures of the baths, and suitable means for measuring the resistance of the specimen.

7. BATHS

7.1 Baths for use with alloys with temperature coefficients of 20 ppm per deg. C and less shall consist of chemically neutral oil. The oil shall be of such quantity and so well stirred that the temperature in the region occupied by the specimen and the thermometer will be uniform within 0·1 deg C for any temperature between 0°C and 40°C, and 0·2 deg C for any temperature between 40° and 80°C.

In an automatically controlled bath, the temperature of the bath at any time during the test at any temperature level shall not differ from its mean temperature by more than 0·2 deg C. In a manually controlled bath, when at a nominally constant temperature, the rate of change of temperature at any temperature level shall not exceed 0·2 deg C per minute.

7.2 Baths for use with other alloys, and all alloys outside the temperature range from 0° to 80°C, shall be as follows:

a) Baths for use below 15°C shall consist of chemically neutral toluene, trichlorethylens or equivalent material.

b) Baths for use above 15°C shall consist of chemically neutral oil with a low viscosity and a flash point at least 50 deg C higher than the temperature of use.

The liquid in these baths shall be of such quantity and so well stirred that the temperature in the region occupied by the specimen and the thermometer will be uniform within 0·5 deg C for any temperature up to and including 100°C, and 1·0 deg C for any temperature above 100°C. If the temperature range is less than 100 deg C, the uniformity of temperature shall be correspondingly closer.

The sample shall be rinsed free of oil by immersion in an acetone bath at room temperature before being placed in toluene bath.

8. TEMPERATURE MEASUREMENTS

8.1 In tests on alloy with temperature coefficients of 20 ppm per deg C and less, the temperature shall be measured either with a laboratory type mercurial thermometer or a resistance thermometer. The thermometer shall have sufficient sensitivity to indicate temperature changes of 0·1 deg C. It is sufficiently accurate to measure temperature differences to 0·2 deg C in the range up to and including 40°C, and to 0·4 deg C in the range from 40° to 80°C.

8.1.1 For other alloys, and for all alloys outside the range from 0° to 80°C, the temperature shall be measured to an accuracy of 0·5 deg C or 1 percent of the temperature range, whichever is the smaller.

9. RESISTANCE MEASUREMENT

9.1 The changes of resistance of the specimen shall be measured by apparatus capable of determining such changes to 0·001 percent of the resistance of the specimen.

9.2 The connections between the specimen and the measuring device shall be such that changes in the resistance of these connections due to changes in their temperature do not appreciably affect the measurement of the change in resistance of the specimen.

9.3 The temperature of the measuring apparatus shall not change during the test by an amount sufficient to introduce appreciable errors in the results.

9.4 The test current shall not be of such a magnitude as to produce an appreciable change in resistance of the specimen or measuring apparatus due to the heating effect.

To determine experimentally that the test current is not too large, the specimen may be immersed in a bath having a temperature at which the wire has been found to have a relatively large change in resistance with temperature. The test current is applied and maintained until the resistance of the specimen has become constant. The current is then increased by 40 percent and maintained at this value until the resistance has again become constant. If the change in resistance is greater than 0·001 percent, the test current is too large and should be reduced until the foregoing limitation is reached.

9.5 The measurements shall be made in such a way that the effects of thermoelectromotive forces and parasitic currents are minimized.

9.5.1 Thus, in a bridge circuit, if there is appreciable thermoelectromotive force it may be desirable to close the galvanometer key first. If the galvanometer deflects, it is allowed to reach a steady deflection, and

balance is regarded as having been achieved if there is no further movement of the galvanometer when the battery key is closed. If, however, there is appreciable inductance in the circuit there may be a transient deflection when the battery key is closed, and it is then sometimes better to close the battery key first. The bridge is adjusted until there is no deflection when the galvanometer key is closed, but since the balance may be affected by thermoelectric effects, it is necessary to take another reading with the battery connections reversed. The resistance of the specimen is taken as the mean of the two readings.

9.5.2 If a potentiometer method is used, the specimen under test and a high quality resistance standard are connected in series to a steady and adjustable source of direct current, and the potentiometer is switched alternately to the standard and the specimen. It is unnecessary to standardize the potentiometer against a standard cell, the potentiometer current and/or the current through the specimen may be adjusted so that when connected to the standard the potentiometer balances at some convenient round reading S (such as 1·000 00). The potentiometer is then quickly switched to the specimen and the reading R is taken at balance. The resistance of the specimen is given by:

$$\frac{R}{S} \times \text{resistance of standard}$$

In order to eliminate the effect of thermoelectromotive force, it is desirable to repeat the procedure with both potentiometer current and specimen current reversed. The resistance of the specimen is taken as the mean of the two results.

9.6 Whatever the instrument used for measuring resistance, ranges shall never be changed between observations. Resistance changes should be measured by adjusting the dials of lowest denomination only and, by suitable choice of initial setting, making use of the ' 10 ' position when necessary, the number of dials requiring to be altered during a series of tests should be reduced to the fewest possible.

10. PROCEDURE

10.1 The test specimen shall be connected in the measuring the circuit and shall be entirely submerged in the bath. For a check on the reproducibility of the measurements, an initial resistance measurement shall be made at room temperature. The temperature of the bath shall be raised or the specimen transferred to a bath maintained constant at the highest temperature at which measurements are to be made. When the specimen has attained a constant resistance, the reading of the measuring device and the temperature of the bath shall be recorded.

10.2 The temperature of the test specimen shall then be decreased to the next lower temperature either by cooling the bath and maintaining it

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constant at the next lower temperature, or by removing the specimen to another bath maintained at the lower temperature. When the resistance of the specimen has become constant observations of resistance and temperature shall again be made.

10.3 In tests on alloys of the copper/manganese type with an approximate composition 84/12, a series of determinations shall be made in this manner over the desired temperature range, the temperature being decreased in steps of 4 to 6 deg C in the range from 40° to 20°C and at intervals of approximately 25 deg C outside this range. Tests shall be made at not fewer than four temperatures.

In tests on other materials, if results are required in the form of a resistance-temperature equation or if it is desired to check the constancy of the temperature coefficient with temperature, the same procedure shall be followed except that the temperature intervals may be up to 25 deg C over the whole of the range.

10.4 A final measurement shall be made at the same temperature as used for initial measurement in 10·1. If this resistance value differs from the initial value by more than 0·002 percent after allowance has been made for any change in the room temperature, the test shall be repeated.

NOTE — It is preferable to make the initial and final measurement at 27°C.

10.5 Where the results are required in the form of a resistance change between two specified temperatures, as in an acceptance test for example, measurements may be made at these two temperatures only, but the determination shall be repeated as a check. The actual temperatures at which these measurements are made shall then be within ± 2 deg C of the required temperatures, but measured with the accuracies specified in this standard.

11. RESISTANCE-TEMPERATURE EQUATION

11.1 The results may be expressed in terms of the constant in an equation of the following form:

$$R_\theta = R_{27} [1 + \alpha_{27} (\theta - 27) + \beta_{27} (\theta - 27)^2]$$

where

$R_\theta =$ the resistance of the specimen at $\theta°C$,

$R_{27} =$ the resistance of the specimen at the reference temperature of 27°C, and

α_{27} and $\beta_{27} =$ the temperature-resistance constants of the material at reference temperature of 27°C.

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12. CALCULATION OF CONSTANTS

12.1 Alloys of the Copper/Manganese Type with an Approximate Composition 84/12

12.1.1 The values of α_{27}, β_{27} and R_{27} may be determined by selecting the measured values of $R\theta$ at three well separated temperatures, inserting the values $R\theta$ and θ in the equation given in **11** to form three equations, and solving for R_{27}, α_{27} and β_{27}.

12.1.2 When the measurements have not been made at exactly 27°C, the value of R_{27} may be read from a curve plotted from the observed values of resistance and temperature. Two additional points may then be selected on the curve, one, θ_1, at least 5 deg C below the reference temperature of 27°C and the other, θ_2, near the highest temperature measured, but satisfying the following relation:

$$K(27 - \theta_1) = \theta_2 - 27 = K\triangle\theta$$

where

K is for ease of calculation, generally taken as an integer.

Example:

If θ_1 is 10 deg C below the reference temperature, then θ_2 should be 10 or 20 or 30 deg C, etc, above the reference temperature for greatest ease of calculation, so that $K = 1$ or 2 or 3 respectively.

If R_1 is the resistance at the temperature θ_1 and R_2 is the resistance at the temperature θ_2, then:

$$\alpha_{27} = \frac{(R_2 - R_{27}) - K^2(R_1 - R_{27})}{R_{27} \, K(K + 1) \, \triangle\theta}$$

$$\beta_{27} = \frac{K(R_1 - R_{27}) + (R_2 - R_{27})}{R_{27} \, K(K + 1) \, (\triangle\theta)^2}$$

If $K = 1$, this simplifies to:

$$\alpha_{27} = \frac{R_2 - R_1}{2 R_{27} \triangle\theta}$$

$$\beta_{27} = \frac{R_1 + R_2 - 2 R_{27}}{2 R_{27} \, (\triangle\theta)^2}$$

If, instead of measuring the actual resistances at the different temperatures, the change in resistance relative to the resistance at 27°C is measured, the above formulae take a slightly different form, as follows:

Let $\triangle R_1$ represent the change in resistance in ohms per ohm in going from 27°C to θ_1, $\triangle R_2$ the similar change in going from 27°C to θ_2, that is

$$\triangle R_1 = \frac{R_1 - R_{27}}{R_{27}} \text{ and } \triangle R_2 = \frac{R_2 - R_{27}}{R_{27}}$$

Then $\quad \alpha_{27} = \dfrac{\triangle R_2 - K^2 \triangle R_1}{K(K+1) \triangle\theta}$

$\qquad \beta_{27} = \dfrac{K \triangle R_1 + \triangle R_2}{K(K+1)(\triangle\theta)^2}$

If $K = 1$, this simplifies to:

$\qquad \alpha_{27} = \dfrac{\triangle R_2 - \triangle R_1}{2\triangle\theta}$

$\qquad \beta_{27} = \dfrac{\triangle R_1 + \triangle R_2}{2(\triangle\theta)^2}$

NOTE — The purchaser should make it clear when asking for details of alloys of the copper/manganese type with an approximate composition 84/12, whether he requires the information in the form of constants α and β or whether a curve of resistance against temperature will suffice. If a curve is provided, it should be such that the constants α and β may be obtained from it alone, with substantially the same accuracy as from the numerical results. The points corresponding to actual measurements made on the specimen should be clearly distinguished on the curve.

12.2 Other Materials — The value of the temperature coefficient of resistance in parts per million per deg C shall be calculated, using the following formula:

$$\text{Temperature coefficient of resistance in parts per million per deg C} = \dfrac{R_2 - R_1}{R_1(\theta_2 - \theta_1)} \times 10^6$$

where

$\qquad R_1 =$ resistance in ohms of the specimen at the lower temperature,

$\qquad R_2 =$ resistance in ohms of the specimen at the higher temperature,

$\qquad \theta_1 =$ temperature in °C of the bath at the lower temperature, and

$\qquad \theta_2 =$ temperature in °C of the bath at the higher temperature.

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INTERNATIONAL SYSTEM OF UNITS (SI UNITS)

Base Units

Quantity	Unit	Symbol
Length	metre	m
Mass	killogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
Amount of substance	mole	mol

Supplementary Units

Quantity	Unit	Symbol
Plane angle	radian	rad
Solid angle	steradian	sr

Derived Units

Quantity	Unit	Symbol	Conversion
Force	newton	N	$1\ N = 1\ kg.\ 1\ m/s^2$
Energy	joule	J	$1\ J = 1\ N.m$
Power	watt	W	$1\ W = 1\ J/s$
Flux	weber	Wb	$1\ Wb = 1\ V.s$
Flux density	tesla	T	$1\ T = 1\ Wb/m^2$
Frequency	hertz	Hz	$1\ Hz = 1\ c/s\ (s^{-1})$
Electric conductance	siemens	S	$1\ S = 1\ A/V$
Pressure, stress	pascal	Pa	$1\ Pa = 1\ N/m^2$

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